RFL Industries, Inc.
Boonton, New Jersey, U.S.A.

Serial # 428

Manual of Instructions

Model 1207

75-200 mc

Crystal Impedance Meter

AN/TSM-15

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Boonton, New Jersey, U. S. A.

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General Description

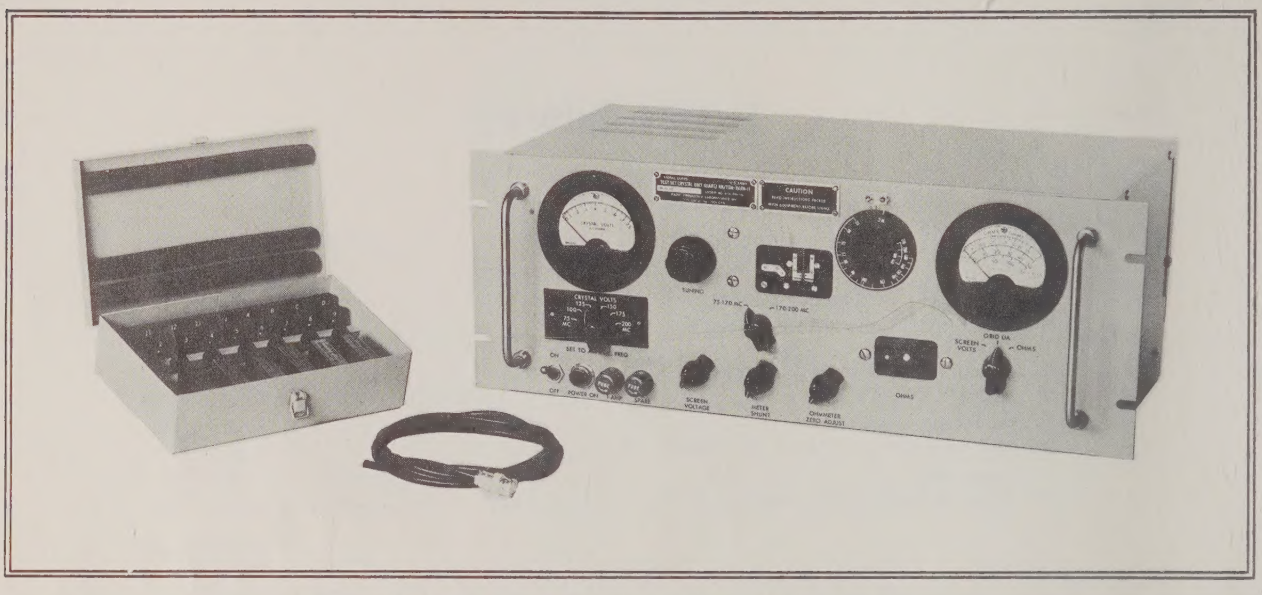

Figure 1. Crystal Impedance Meter, Model 1207.

PURPOSE

The purpose of this handbook is to provide operating and servicing personnel with the necessary information concerning the installation, operation and maintenance of the Crystal Impedance Meter Model 1207.

The Crystal Impedance Meter Model 1207 is designed to measure directly the effective resistance of quartz crystal units at resonance and/or at series resonance in the frequency range of 75 to 200 megacycles. Crystals mounted in either the HC-6/U or HC-18/U holders can be tested.

DESCRIPTION

The Crystal Impedance Meter Model 1207 consists of a high frequency two tube variable frequency oscillator, a power supply, a crystal diode type voltmeter circuit across the crystal socket, and an ohmmeter to measure the resistance of the substitution resistors. A set of eighteen preset inductances are furnished with the Model 1207. Fourteen are employed to cancel the C_o' of quartz crystal units. All inductances are employed to determine the C_o' of crystals between 5.0 and 11.0 uuf.

Note: The suffix is assigned to the high frequency C_o value to distinguish it from the low value C_o.

The variable frequency oscillator covers two bands, 75 to 170 mc and 170 to 200 mc. Two panel meters are provided. One is used only to measure the r-f voltage across the crystal socket, from which measurement the power dissipated in the crystal may be computed. The second meter is used with a function switch to measure the screen volts of the oscillator tube, the grid microamperes of the oscillator tube, and the resistance of a substitution resistor. Two socket faces are used, one for r-f measurements and one for the measurement of the D C resistance of the substitution resistors. The eighteen inductances and six resistances are furnished in a gray steel box.

The Crystal Impedance Meter Model 1207 operates from a power source of 115 volts or 230 volts A C, 50 to 1000 cps. It is enclosed in a metal case designed for

Figure 2. Variable High Frequency Resistors and C_o Cancellation Inductances.

standard rack and panel mounting. The panel dimensions are 19 inches long by 7 inches high. The over-all depth is 10-1/2 inches.

DESCRIPTION OF MINOR COMPONENTS

C_o' Cancellation and C_o' Determination Inductances. - When the inductances shown in the table are used for C_o' cancellation they are plugged in parallel with the crystal units and are chosen to resonate with the C_o' of the crystals.

When the inductances are used for C_o' determination they are plugged in series with the crystal units between crystal socket and ground. The proper inductance for C_o' determination is the inductance that will give a minimum impedance about 3-5 mc below the operating crystal frequency. Reference is made to the curves shown in Figure 7 for the C_o' value of the crystal unit.

Other methods of C_o' determination are the Boonton Radio Q Meter, type 190-A, and R-X Meter model 250-A. For these methods C_o' is determined approximately 500 kc below the crystal frequency.

Table 1.

C_o' CANCELLATION AND C_o' DETERMINATION INDUCTANCES

#1	.0617 uh	205 mc	#12	.192 uh	140 mc
#2	.0670 uh	200 mc	#13	.224 uh	130 mc
#3	.0727 uh	195 mc	#14	.271 uh	125 mc
#4	.0790 uh	190 mc			
#5	.0864 uh	185 mc	A	.0435 uh	200 mc
#6	.0954 uh	180 mc	B	.0472 uh	200 mc
#7	.105 uh	175 mc	C	.0517 uh	200 mc
#8	.116 uh	170 mc	D	.0565 uh	200 mc
#9	.131 uh	165 mc			
#10	.146 uh	160 mc			
#11	.166 uh	150 mc	22-ohm resistor		

Table 2.

TECHNICAL CHARACTERISTICS

The electrical characteristics of the Crystal Impedance Meter Model 1207 are as follows:

Measurements	Effective resistance of crystal at resonance and/or series resonance.
Frequency range	2 bands 75-170 mc and 170-200 mc.
Resistance calibration	10-100 ohms at $\pm 10^{o}$ phase angle, five compensated and 1 uncompensated variable resistors provided to cover the frequency range.
Crystal unit capacitance	5.5 uuf minimum to 10.5 uuf maximum.
Accuracy of measurement	Equivalent effective resistance is within ± 5 ohms or $\pm 10\%$.
Crystal Unit Power measurement	A crystal diode voltmeter measures the voltage to $\pm 10\%$ across the crystal in resonance and/or series resonance. From the voltage and effective resistance the power dissipated in the crystal is measured to $\pm 30\%$.
Crystal Unit Power regulation	After initial adjustment of the test for a 60-ohm crystal unit, the power dissipated in a 20-ohm crystal is less than twice that dissipated in the 60-ohm crystal.
Ohmmeter	10-1000 ohms DC resistance.
Number of Tubes	Four. V1 5Y3GT/G Rectifier V2 OA2 Voltage Regulator V3 6AN4 Ground Grid Amp. V4 6AK5/5654 Oscillator Tube

The proper inductance for C_o' cancellation is chosen from the curves shown in Figure 8.

Variable H. F. Substitution Resistors. - The six variable include one uncompensated resistor and five with series capacitors for compensation of the phase angle to $\pm 10^{o}$ over a limited frequency range. The resistor elements consist of thin metallic films of Nichrome deposited on pyrex glass with gold plated beryllium copper sliding contacts. The proper variable resistor is selected as described in the Operation Section.

A small enameled grey steel box is provided to hold the fourteen C_o cancellation inductances and the six variable substitution resistors.

Installation and Adjustment

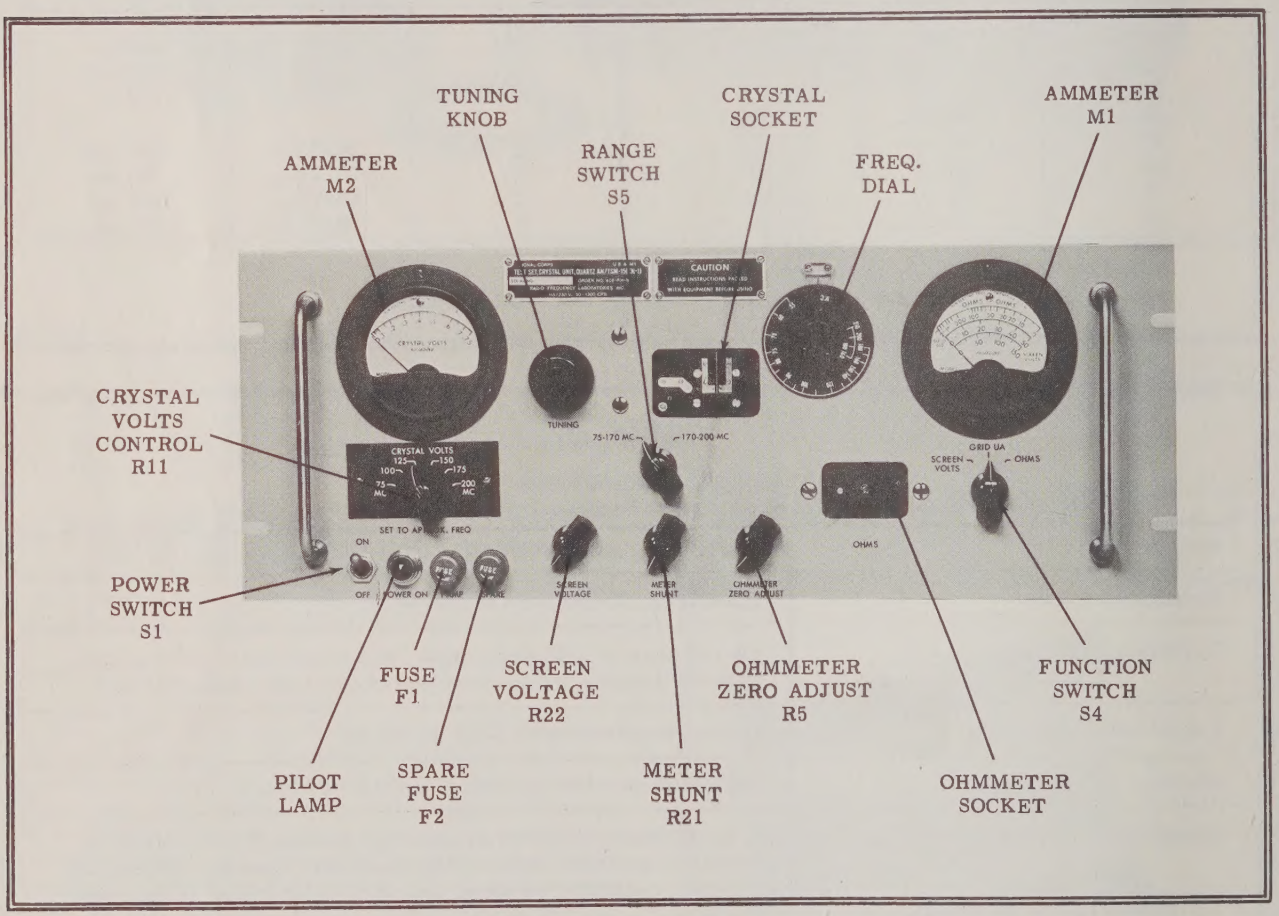

Figure 3. Front Panel View of Crystal Impedance Meter, Model 1207.

UNPACKING THE EQUIPMENT

Cut the metal bands. Open the cartons that protect the equipment; or, if heavy wrapping has been used, remove it carefully and take out the components. Check the contents of the packing case against the master packing slip.

Note: Save the original packing cases and containers. they can be used again when the equipment is repacked for storage or shipment.

CAUTION

Be careful in unpacking and handling equipment; it is easily damaged. If it becomes damaged or exposed, a complete overhaul might be required or the equipment might be rendered useless.

INSTALLATION OF EQUIPMENT

The following steps should be followed in the installation of the equipment:

1. Check the contents of the packing case against the master packing list.

2. Thoroughly inspect the exterior of the Crystal Impedance Meter for possible damage in shipment.

3. Loosen the nine binding head screws on the sides and back of the unit and remove the metal dust cover. Also remove the bottom cover plate.

4. Make sure the vacuum tubes are not broken and that they are seated properly in their sockets. (Note that both oscillator tube and amplifier tube are located underneath the chassis).

5. Inspect the wiring to make certain that the leads are securely fastened to points of contact.

6. Inspect the sub-assembly parts such as the terminal strips to make certain they are securely fastened in place.

CAUTION

The chassis of the Crystal Impedance Meter has been moistureproofed and fungiproofed. Do not remove any of the protective coating.

7. Remove the cap from the fuseholder (Figure 11) and see that the fuse (1-ampere) has been installed.

8. Replace dust cover and bottom cover plate.

CONTROLS AND INSTRUMENTS

Haphazard operation or improper setting of the controls can cause damage to electronic equipment. For this reason it is important to know the function of every control.

The actual operation of the equipment is discussed in the Operation Section of this book.

Controls and Their Functions. - The following table lists the controls and instruments on the equipment and indicates their functions. Refer to Figure 3 and 11 for illustrative identification of these controls and instruments.

CAUTION

It is of great importance that the line voltage change-over switch S2 (Fig. 11) on the rear of the unit be set correctly and locked in the operating voltage position. SCREEN VOLTAGE control R22 should be set to its lowest value (extreme counter-clockwise position) before the POWER ON-OFF switch S1 is turned to the ON position.

Table 3.

CONTROLS AND THEIR FUNCTIONS

ON-OFF switch S1.	Switches power on and off when the Crystal Impedance Meter connected to power source.
115 V or 230 V Voltage-Change-Over switch S2 (located on rear of chassis).	Connects the power transformer primary windings for 115- or 230-volt operation.
Microswitch S3.	Opens short across ohmmeter socket upon insertion of resistor.
Function Switch S4.	Switches meter M1 to measure SCREEN VOLTS, GRID UA, and OHMS.
75-170 MC; 170-200 MC range switch.	Changes tuning range of the oscillator.
SCREEN VOLTAGE potentiometer R22.	Adjusts the screen voltage of the oscillator tube.
METER SHUNT control R21.	Varies the grid current meter sensitivity.
OHMMETER ZERO ADJUST control R5.	Adjusts the ohmmeter zero.
TUNING.	Tunes oscillator to frequency desired.
Crystal Volts Adjust.	Adjusts the sensitivity of the r-f voltmeter to compensate for reduced rectification efficiency at the high frequencies.

Operation

STARTING PROCEDURE

Perform the starting procedure given below before using the operating procedure described in the following paragraph. If any abnormal condition is observed during the starting procedure, throw the ON-OFF switch to the OFF position, disconnect the power cable, and refer to the equipment performance check list (Table 8).

Note: All initial adjustments on the Crystal Impedance Meter are made at the factory; field adjustments should not be necessary.

1. Set METER SHUNT control fully clockwise and the function switch S4 to GRID UA.

2. Set SCREEN VOLTAGE control fully counter-clockwise.

3. Determine whether the power source is 115 volts or 230 volts, and set VOLTAGE Change-Over switch S2 (located on rear of chassis) to the proper value. The proper setting for either source voltage is marked clearly on the chassis.

4. Insert the power cord into the AC outlet.

5. Connect the r-f output jack J1 to frequency measuring equipment of the desired accuracy and a radio receiver covering the frequency range of the meter.

MEASUREMENT OF
RESONANCE RESISTANCE 75-125 MC.

Switch the ON-OFF switch to the ON position. Allow the Crystal Impedance Meter to warm up for 15 minutes. Set the range switch to 75-170 mc. Set the CRYSTAL VOLTS control to approximate the crystal frequency.

To measure the resonant resistance of the crystal insert it in the socket and proceed as follows:

With the METER SHUNT set at maximum clockwise position, increase the SCREEN VOLTAGE control while tuning through the crystal frequency until oscillation occurs as indicated by a peak on the GRID UA meter.

Adjust the SCREEN VOLTAGE control for 1/2-scale reading of the GRID UA meter.

Tune the radio receiver with a BFO to the crystal controlled Crystal Impedance Meter frequency and note the GRID UA reading.

Remove the crystal unit and inductance and replace with a V. H. F. variable resistor. This resistor is selected by using the frequency of operation as a guide.

Adjust the H. F. variable resistor until the same grid μa reading is obtained as with the crystal. Rotate the TUNING control until the same frequency is found as in the above step.

Remove the V. H. F. variable resistor and plug it into the OHMS socket. Set the function switch to OHMS and read the resistance of the substitution resistor.

With this value of resistance calculate the required voltage across this resistance for the drive level in watts desired from $E = \sqrt{PR}$ (P = watts, R = ohms). Adjust

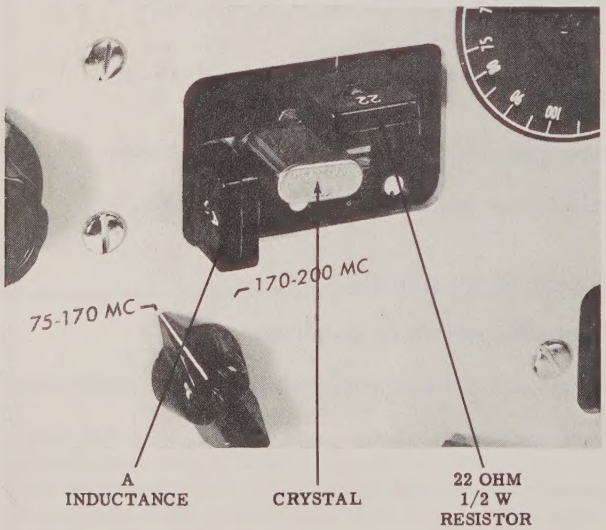

Figure 4. Front View of Socket Face Showing Arrangement of Parts for the Measurement of C_O.

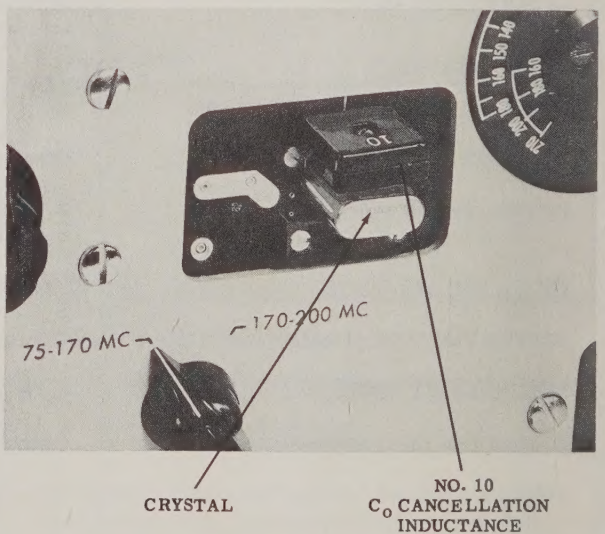

Figure 5. Front View of Socket Face Showing Arrangement of Parts for Measurement of Equivalent Series Resonant Resistance.

the SCREEN VOLTAGE control until the CRYSTAL VOLTS meter reads the calculated voltage.

Replace the crystal and correct the drive level (CRYSTAL VOLTS reading).

Retune the radio receiver and measure the exact frequency output, if necessary.

Remove the crystal unit and plug in the variable resistor. Correct the resistor adjustment to give the crystal grid μa reading and readjust the TUNING control to obtain the same frequency as when the crystal and inductance is plugged in.

Remove the variable resistor, plug it into the OHMS socket and measure its resistance. This resistance is the effective resonance resistance of the crystal unit and the frequency as measured in the above step is the series resonant crystal frequency.

MEASUREMENT OF
SERIES RESONANCE RESISTANCE 125-200 MC.

Switch the ON-OFF switch to the ON position. Allow the Crystal Impedance Meter to warm up for 15 minutes. Set range switch to the desired frequency range, 75-170 mc or 170-200 mc. Set the CRYSTAL VOLTS control to approximate crystal frequency.

Select the proper C_o' Cancellation Inductance. This is done by first measuring the C_o' of the crystal unit, then with this value of C_o' entering the curves of Figure 8 and obtaining the correct inductance to resonate with the C_o' of the crystal unit at its operating frequency. The curves of Figure 7 and the connecting lug on the socket face can be used as shown below to measure the C_o' of a crystal unit. C_o' can also be measured using a high frequency Q meter or impedance meter at the frequency of use. To use Figures 7 and 8 to select the proper inductance proceed as follows:

Plug the crystal unit and a first guess inductance into the left side of the socket face as shown in Figure 4. A 22-ohm resistor is plugged across the normal crystal socket.

Increase the SCREEN VOLTAGE control until oscillation occurs as indicated by the GRID UA meter. Turn the TUNING knob to vary the frequency and tune to a resonant dip. Observe the frequency of oscillation on the external frequency meter or calibrated radio set. Select a coil that has the resonant dip 3-5 mc below the crystal unit frequency. The crystal unit frequency can be detected by a sharp increase in grid μa reading. The 75-170 mc - 170-200 mc range switch should be set for the crystal unit.

With the frequency of series resonance for the coil-crystal combination enter the curves of Figure 7 for the inductance used and obtain the value of C_o' for the crystal unit in μμf.

With the value of C_o' enter the curves of Figure 8 and select the closest inductance that will resonate with C_o' at the crystal frequency.

To measure the series resonant resistance of the crystal remove the units from the socket face and plug in the crystal unit and C_o' cancellation inductance in parallel as shown in Figure 5 and proceed as follows:

With the METER SHUNT at the maximum clockwise position, increase the SCREEN VOLTAGE control while tuning through the crystal frequency until oscillation occurs as indicated by a peak on the GRID UA meter.

Adjust the SCREEN VOLTAGE control for 1/2-scale reading of the GRID UA meter.

Tune the radio receiver with a BFO to the crystal controlled test set frequency and note the GRID UA reading.

Remove the crystal unit and inductance and replace with a V.H.F. variable resistor. This resistor is selected by using the frequency of operation as a guide.

Adjust the H.F. variable resistor until the same grid μa reading is obtained as with the crystal. Rotate the TUNING control until the same frequency is found as in the step above.

Remove the V.H.F. variable resistor and plug it into the OHMS socket. Set the function switch to OHMS and read the resistance of the substitution resistor.

With this value of resistance calculate the required voltage across this resistance for the drive level in watts desired from $E = \sqrt{PR}$ (P = watts, R = ohms). Adjust the SCREEN VOLTAGE control until the CRYSTAL VOLTS meter reads the calculated voltage.

Replace the crystal and C_o' inductance and correct the drive level (CRYSTAL VOLTS reading).

Retune the radio receiver and measure the exact frequency output, if necessary.

Remove the crystal unit and plug in the variable resistor. Correct the resistor adjustment to give the crystal grid μa reading and readjust the TUNING control to obtain the same frequency as when the crystal and inductance is plugged in.

Remove the variable resistor, plug it into the OHMS socket, and measure its resistance. This resistance is the effective resonance resistance of the crystal unit and the frequency as measured in the above step is the series resonant crystal frequency.

Theory of Operation

CRYSTAL PARAMETERS

Piezoelectric Effect. - When an electrical stress is applied to a cut quartz crystal in the direction of one of the major axes, a mechanical stress is produced at right angles to this axis. Conversely, a mechanical stress along a major axis will cause electrical charges to appear on the faces of the crystal perpendicular to the stress axis. The polarity of the electrical stress and the direction of the corresponding mechanical force are interrelated; a reversal in one causes a reversal in the other. This relationship between electrical stress and mechanical force is termed the piezoelectric effect and provides a means of relating mechanical vibrations to electrical circuits.

Resonance. - An alternating voltage applied across a quartz crystal will cause the crystal to vibrate; if the frequency of the applied alternating voltage approximates a frequency at which mechanical resonance can exist in the crystal, the amplitude of the vibrations will be very large. Any crystal has several such resonant frequencies that depend on the crystal dimensions, the type of oscillation involved, and the orientation of the plate cut from the natural crystal.

Properties of Piezoelectric Resonator. - A good piezoelectric resonator possesses the following properties: a low-temperature coefficient of resonant frequency, a high piezoelectric activity (performance index), and a frequency spectrum containing only one resonant frequency in the vicinity of the desired oscillation. Temperature can alter the frequency of mechanical resonance through its effects on the density, the linear dimensions, and the moduli of elasticity of the crystal. Since some of the elastic constants are positive, while others are negative, the temperature coefficient of frequency may be either positive, negative, or zero, according to the mode of oscillation, the orientation of the crystal plate, and the shape of the plate. The electrical circuit associated with a vibrating crystal is shown in Figure 6. The capacity, C_o represents the electrostatic capacity between the crystal electrodes when the crystal is in place but not vibrating; the series combination of L, C, and R represents the equivalent mass, compliance, and frictional loss of the vibrating crystal, respectively.

CRYSTAL PARAMETERS, MEASUREMENT

Static Capacitance, C_o. - The value of the static capacitance of the unit, C_o of low frequency crystals may be measured by any conventional capacitance measuring unit. The effective C_o' capacitance of high frequency crystals must be measured near the crystal frequency because of the effects of lead inductance. If this measurement is made by using a Q meter or an r-f bridge, be careful to select a frequency of operation 0.5 mc lower than the crystal unit frequency. The Crystal Impedance Meter Model 1207 has a connection plate at the side of the crystal socket so that the crystal and an inductance can be connected in series network across the 33-ohm socket resistor to ground. With a resistor or short in the crystal socket resonance is indicated by a dip. The C_o' is determined from Figure 7 for the values of frequency of dip and coil used. As the capacitive reactance of C_o' for high frequency crystals is low and comparable to the effective series resistance it is necessary to place this C_o' cancellation coil in parallel resonance at the crystal unit frequency for accurate measurements of effective series resistance and crystal unit series resonance frequency. The C_o' cancellation coil is determined from Figure 8 for specific value of C_o' and crystal frequency.

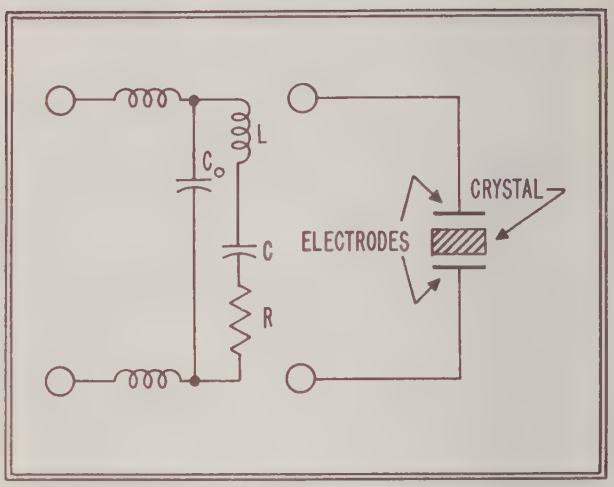

Figure 6. Equivalent Electrical Circuit of a Piezoelectric Crystal.

V. H. F. Variable Resistors. - The V. H. F. resistor uses a thin sputtered film of nichrome #5 on pyrex glass. A gold plated beryllium copper spring is used as a contact making slider. All resistors are constructed identically except for the value of the series compensating capacitor. One unit is provided without a capacitor. All units cover the range of 10 to 100 ohms. The resistor number and value of internal series capacitor are listed below.

VARIABLE HIGH FREQUENCY RESISTORS

V. H. F. Variable Resistor	Series Capacitor	Usual Frequency Range of Use
1	Uncompensated	
2	180 μμf	75-100 MC
3	91 μμf	100-125 MC
4	75 μμf	125-150 MC
5	47 μμf	150-175 MC
6	39 μμf	175-200 MC

The curves of Figure 9 show the resistance vs. frequency area for each resistor in which the phase angle of the resistors are less than 10°.

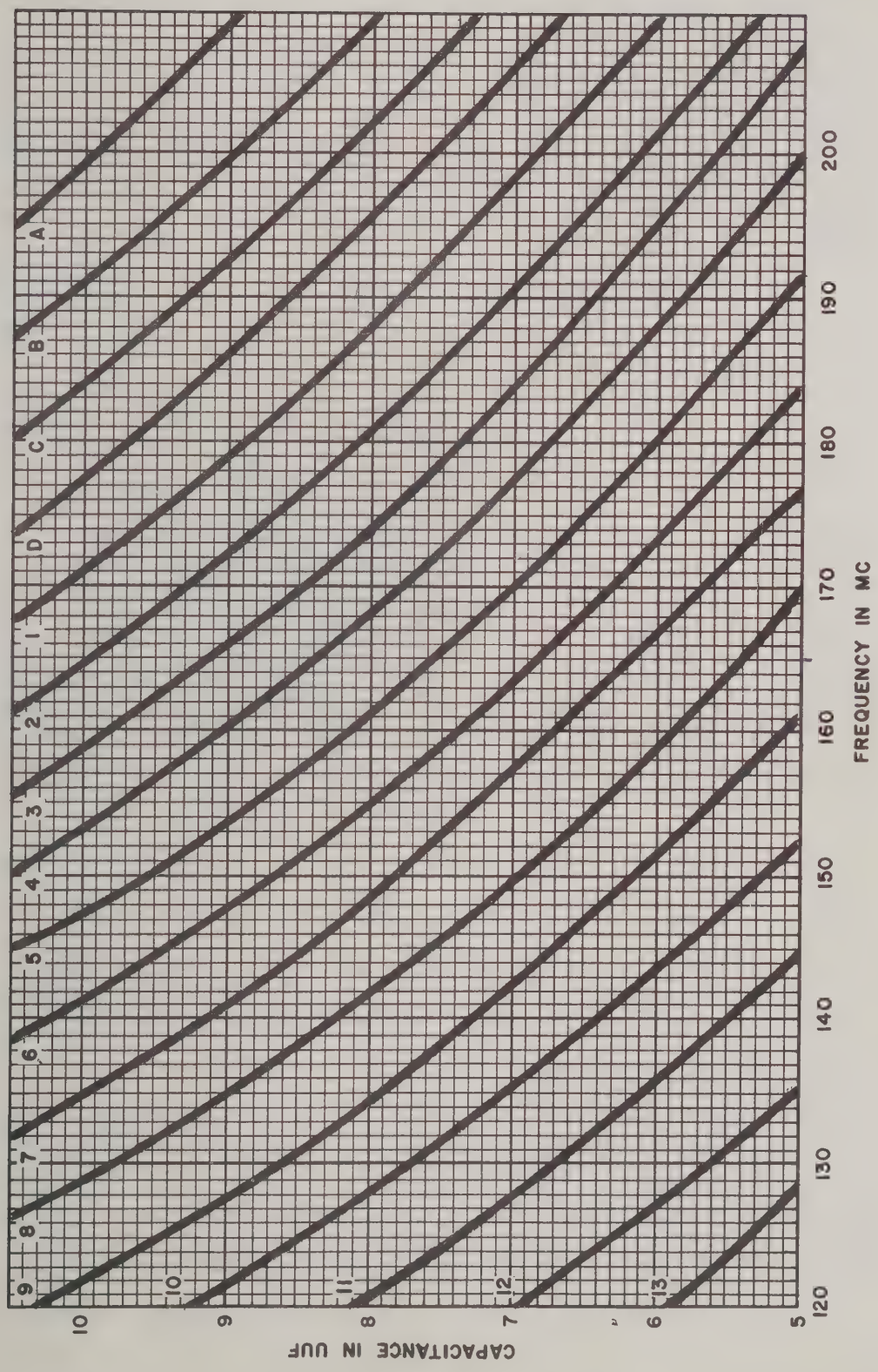

Figure 7. Curves for the Determination of C_o of Crystal Unit.

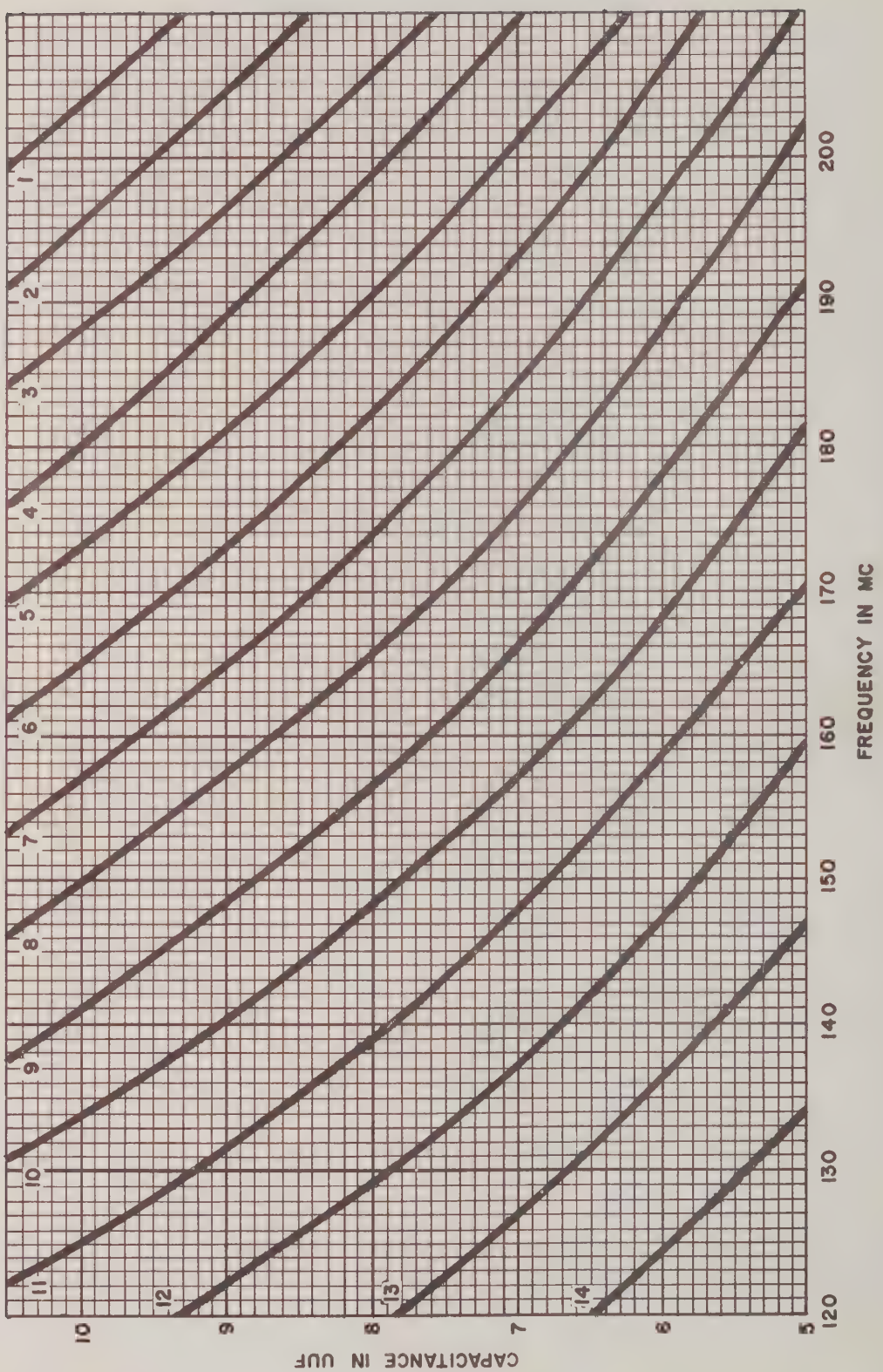

Figure 8. Curves for Selection of C_o Cancellation Coil.

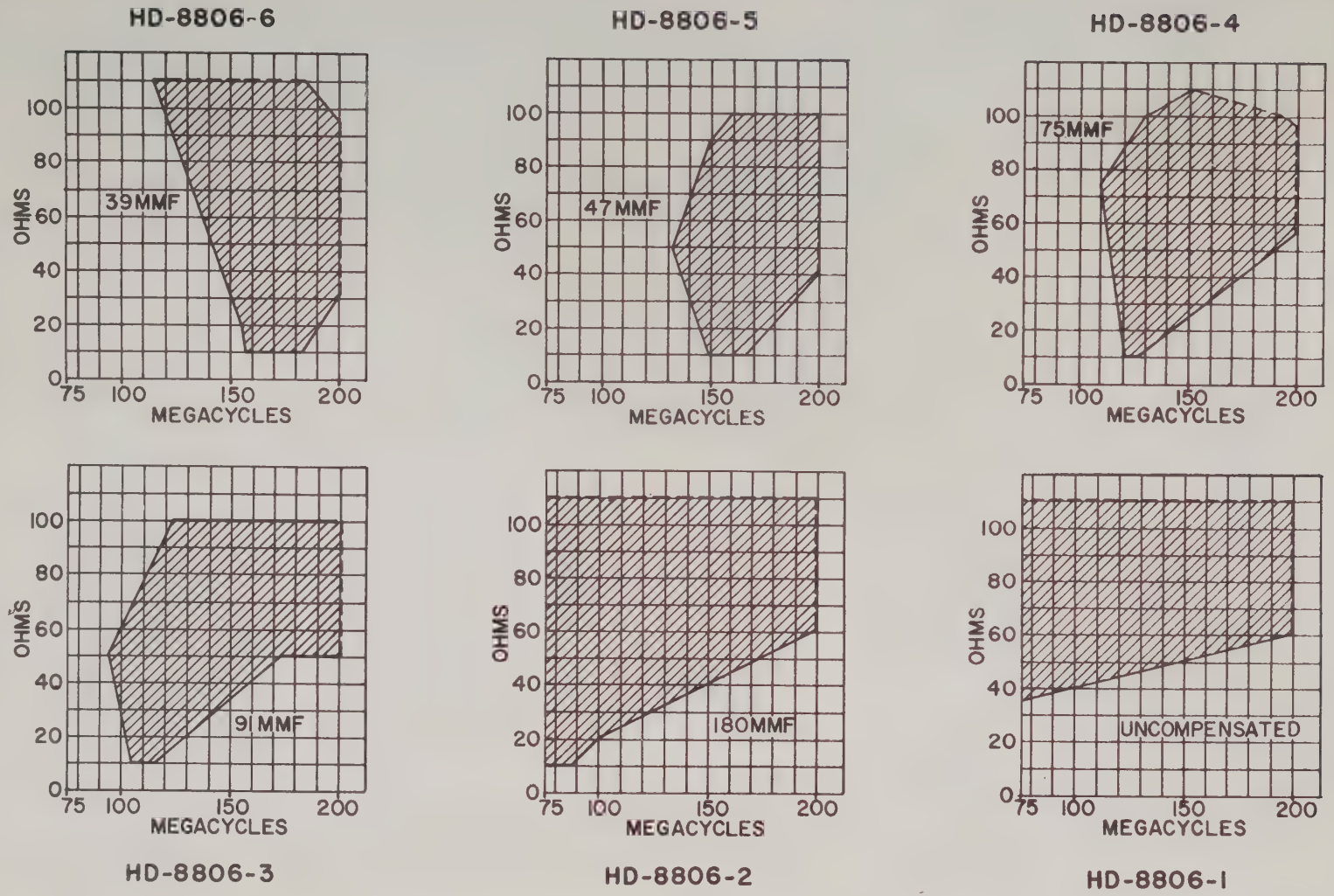

Figure 9. Curves Showing the Resistance vs. Frequency Area of Use of the Variable Resistors.

FUNCTIONING OF CRYSTAL IMPEDANCE METER MODEL 1207

The Crystal Impedance Meter Model 1207 is essentially a two-tube tuned-plate oscillator circuit in which the crystal unit to be tested is placed in the feedback path. The crystal unit thus controls the oscillation frequency of the circuit and the amplitude of oscillation. The effective resistance of the crystal unit is measured by application of the following principle of substitution: In any system, if an element of the system is removed and a substitute element is inserted, so that the original set of boundary conditions is satisfied and no new ones are added, then the substitute element is equivalent operationally to the original element. Thus, if the boundary conditions (oscillation frequency and amplitude of oscillation) are measured at some point in the circuit, a network of resistance and reactance is substituted for the crystal unit without changing the boundary conditions; then the network represents the crystal unit at that particular frequency and amplitude of oscillation. Crystal units are operated at their resonant frequencies from 75 mc to 125 mc and series resonant frequencies from 125 mc to 200 mc.

In actual use, the exact resonance frequency or series resonant frequency may be unknown. The circuit of the Crystal Impedance Meter Model 1207 (connected to appropriate frequency measuring equipment) is tuned first to the approximate frequency; then, by alternate adjustment of the value of the substitution resistance and of the circuit tuning, the correct frequency and value of resistance are obtained. Generally, adjustment must be made only two or three times before complete satisfaction of the boundary conditions is attained. These adjustments may be compared with the resistance and reactance adjustments performed when balancing an impedance bridge.

POWER SUPPLY

The power supply is a conventional type that converts 115 or 230 volts AC, 50 to 1,000 cps to the regulated voltage necessary for the plate supply of tube V3 and tube V4. The power supply uses rectifier tube V1 (5Y3GT) in a full-wave circuit and tube V2 (0A2) as a voltage regulator. A 1-ampere fuse (F1) opens the circuit if an overload or short occurs inside the Crystal Impedance Meter. Voltage Change-Over switch S2 adapts the unit for operation on either 115 or 230 volts AC, 50-1,000 cps by connecting the two halves of the primary winding in parallel or in series.

Transformer T1 has a primary rating of 115 or 230 volts AC, single-phase, with output windings on the secondary of 700 volts at 35 ma center-tapped for the plates of V1, 5.0 volts at 3.0 amperes for the filament of V1, and 6.3 volts at 2.5 amperes for the filaments of V3, V4, and pilot lamp E1. The rectified voltage is taken off one side of the filament of rectifier tube V1.

The rectified output of V1 is filtered free of ripple by resistors R1, R2, and R3 and capacitors C2A and C2B. The filter is connected to voltage-dropping resistor R3 which, in turn, is connected to voltage regulating tube V2. The tube V2, operating in conjunction with resistor R3, maintains the voltage across its terminals constant at approximately 150 volts, despite normal changes in line voltage and current drain of the connected circuits.

The screen grid of the oscillator tube in use is supplied with DC voltage controlled by potentiometer R22 (SCREEN VOLTAGE) connected across the voltage regulator tube V2. This screen grid voltage controls the amplitude of oscillations. Pilot lamp E1 is operated from the 6.3-volt winding of the secondary of transformer T1. The .003 μf capacitor C1 bypasses r-f current from the input AC power line to ground.

OSCILLATOR CIRCUIT

The oscillator circuit uses one r-f pentode type 5654 (V4) with a tuned plate circuit and one r-f triode type 6AN4 (V3) as a grounded grid amplifier with a tuned plate circuit. The feedback path through the crystal or substitution resistor converts the amplifier into an oscillator. The two frequency bands 75-170 mc and 170-200 mc are selected by band switch S5. The switch S5 adds the 1$\mu\mu$f capacitor C19 to increase the phase shifts of the tuned circuit at the low frequency end of the range. The 1.5-7 $\mu\mu$f capacitor C15 is adjusted for optimum operation at 180 mc. The grounded grid amplifier tube V3 (6AN4) has a tuned circuit in its cathode circuit that is tuned for 180 mc. This tuned circuit increases the high frequency gain of the amplifier. The amplitude of oscillation is indicated by measuring the grid μa of V4 with the meter M1.

FEEDBACK NETWORK AND CRYSTAL SOCKET

The feedback circuit is placed between the plate of circuit of V4 and the cathode of V3. The driving voltage is coupled from the tank circuit of V4 through the 470 $\mu\mu$f capacitor to the 33-ohm socket resistor R17. The crystal is plugged between the 33-ohm resistors R17 and R14. The voltage across R14 is coupled to the cathode of V3. The crystal socket is provided with a connection plate so that the crystal and a C_o' cancellation inductance can be connected in series across the 33-ohm resistor R17. When a resistor is plugged into crystal socket to complete the feedback loop the magnitude of oscillations of the circuit is depressed at the resonant frequency of the C_o' of the crystal and inductance.

CRYSTAL VOLTMETER CIRCUIT

The voltage across the crystal or substitution resistor is measured by means of the silicon diode CR2 (1N25), the filter capacitor C12, the filter resistors R15 and R16 and fixed resistor R10 feeding the 50 μa meter M2. The 5 K potentiometer R11 corrects for high frequency characteristics of the 1N25 diode. The 50 $\mu\mu$f capacitor C12 is constructed into the brass block of the socket face.

OHMMETER

A single range DC ohmmeter is provided in the equipment by rectifying the 6.3 v AC output of transformer T1 with a 1N91 germanium rectifier. The current through the unknown resistor is indicated by the meter M1 which is calibrated in ohms. The OHMS socket face is designed

so that it is shorted unless a V. H. F. variable resistor is plugged in. A contact is provided to pick up the resistive elements of the resistor. The V. H. F. variable resistor must be plugged into the socket with the knob to the right.

Maintenance

GENERAL

Periodic inspection should be made to see that all the screws are tight. If trouble should develop in the sealed meter (M1), it should be replaced from the factory and no attempt made to repair it.

LUBRICATION

The following precautions should be observed when the Crystal Impedance Meter Model 1207 is lubricated.

Do not use excessive amounts of oil or grease and do not allow connections to become greasy.

Be sure that lubricants and points to be lubricated are clean and free from sand, grit, or dirt. These abrasives are the chief cause of bearing wear and their presence often necessitates bearing replacements. Before lubricating, clean all surfaces with a lint-free cloth dampened with a solvent. Keep the solvent off surrounding parts.

Lubrication Instruction. - Lubrication points are illustrated in Figure 10.

Lubrication is performed during manufacture, and with normal care lubrication is ordinarily not required during the life of the equipment. If the equipment is completely overhauled, lubricate in accordance with the information in Figure 10.

Gasoline should not be used as a cleaning fluid for any purpose. When the unit is overhauled or repairs are made, clean the parts with a solvent such as carbontetrachloride.

WARNING

When servicing the Crystal Impedance Meter Model 1207 be extremely careful. High voltage is present. Always disconnect the line plug before making resistance checks in the meter. Before touching any part after the voltage is shut OFF, short the part to chassis.

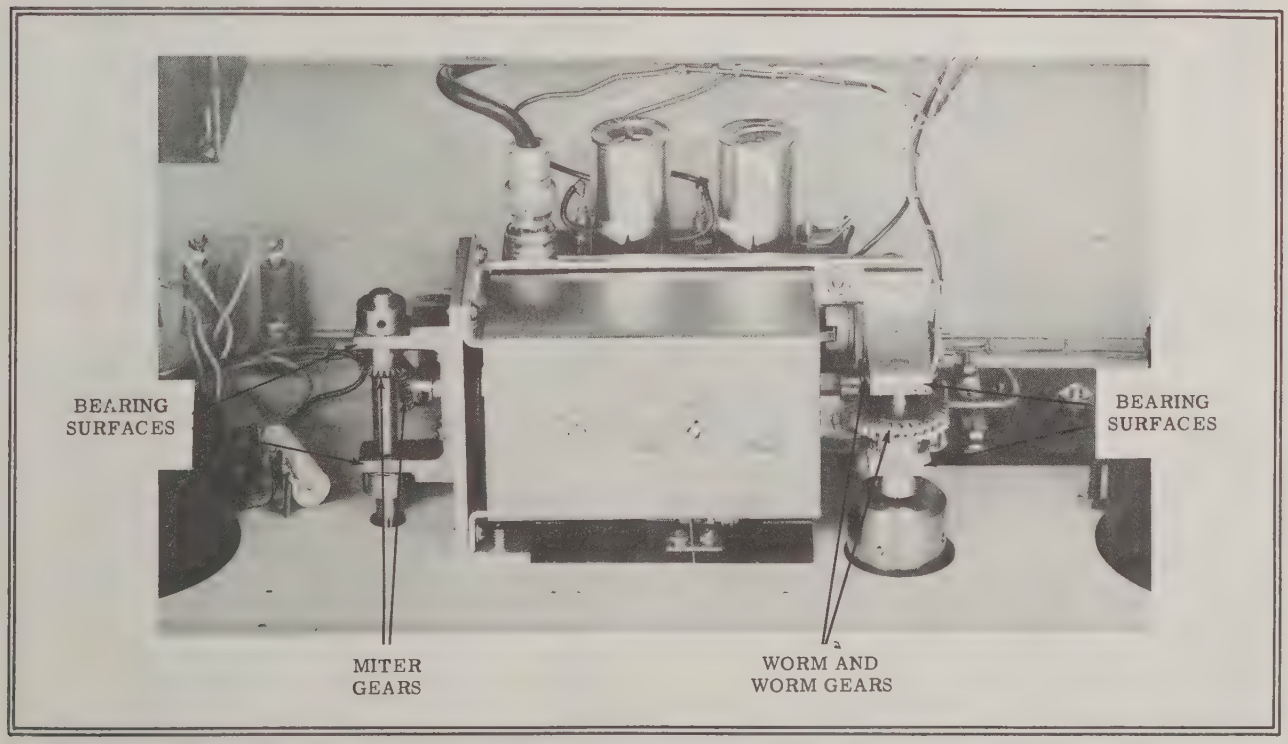

Figure 10. Lubrication Points of Crystal Impedance Meter, Model 1207.

Table 4

LUBRICATION CHART

The following parts listed below have been lubricated by the manufacturer prior to the delivery of the equipment.

COMPONENT	PARTS LUBRICATED	LUBRICANT
Crystal Impedance Meter Model 1207	Teeth of all gears.	Lubri-plate
	Bearings of tuning knob and indicating dial shift.	Oil, engine (SAE 20).
	Two end bearings of tuning indicator shaft.	Oil, engine (SAE 20).

Parts not Requiring Subsequent Lubrication.

COMPONENT	PARTS LUBRICATED	LUBRICANT	REASON SUBSEQUENT LUBRICANT IS NOT REQUIRED
Crystal Impedance Meter Model 1207	Tuning indicator L1A and L1B sliding contacts	Lube-Rex Lubri-plate (General Cement Co. or equivalent).	Under Ordinary service conditions factory lubrication should last for life of unit.

TROUBLE SHOOTING PROCEDURE

Sectionalization and Localization. - The first step in servicing defective test equipment is to sectionalize the fault. Sectionalization means tracing thé fault to the major component or circuit responsible for the abnormal operation of the set. The second step is to localize the fault. Localization means tracing the fault to the defective part responsible for the abnormal condition. Some faults, such as burned out resistors and shorted transformers, can be located by sight or smell. The majority of faults must be located by checking voltage and resistance.

Tests. - The tests listed below aid in isolating the source of trouble. Remember that servicing procedure should cause no further damage to the test equipment. First, trouble should be localized to a single stage or circuit in the equipment. Then the trouble may be isolated within the stage or circuit by appropriate voltage, resistance and continuity measurements.

Through this inspection alone the repairman frequently discovers the trouble or determines the stage in which the trouble exists. This inspection is valuable in order to avoid additional damage which might occur through improper servicing methods and the forestall future failures.

Operational Tests. - The operational tests are important because they frequently indicate the general condition of trouble. In many instances this information will indicate the exact nature of the fault. In order for this information to be utilized fully, all symptoms must be interpreted in relation to another.

The Trouble Shooting Chart listed in Table 5 will aid in localizing trouble.

Intermittents. - In all these tests the possibility of intermittents should not be overlooked. This type of trouble may appear when the set is tapped or jarred. Look for loose connections. It is possible that the trouble is not in the set itself but in the installation, such as cord connections, etc.

VOLTAGE MEASUREMENTS

Voltage measurements are an almost indispensable aid to the repairman because most trouble either results from abnormal voltages or produces abnormal voltages. Voltage measurements are always made between two points in the circuit and the circuit need not be interrupted. Complete information on normal operating voltages is given in Table 6.

Unless otherwise specified, voltages are measured between the indicated points and ground.

Always begin by setting the voltmeter on the highest range in order that the voltmeter will not be overloaded and then, if necessary, set the voltmeter to a lower range.

VOLTMETER LOADING

It is essential that the voltmeter resistance be at least ten times as large as the resistance of the circuit across which the voltage is measured. If the voltmeter resistance is comparable to the circuit resistance, the voltmeter will indicate a voltage lower than the actual voltage present when the voltmeter is removed from the circuit.

To minimize voltmeter loading in high resistance circuits, use the highest voltmeter range. The decreased

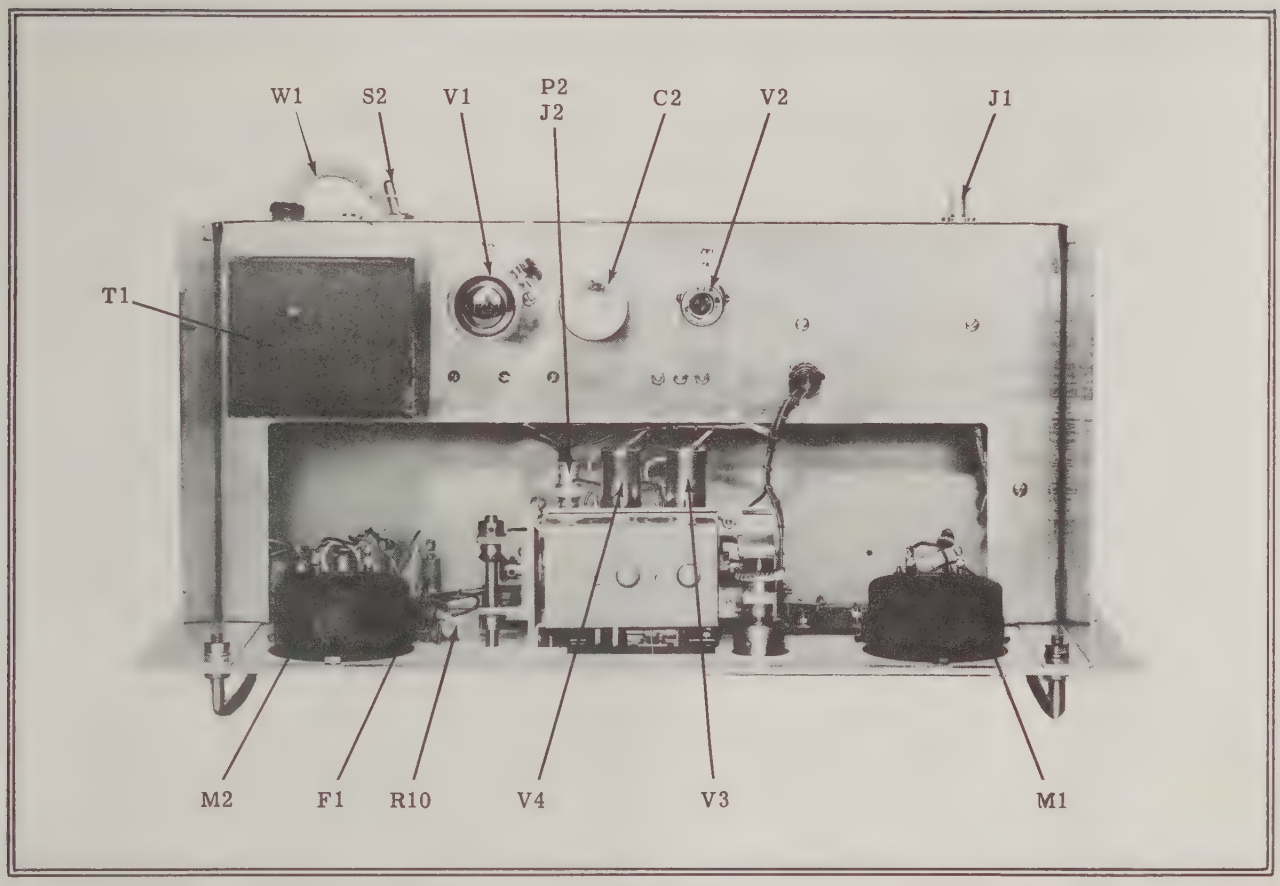

Figure 11. Top View of Panel and Chassis Assembly of Crystal Impedance Meter.

loading caused by the voltmeter will more than compensate for the inaccuracy which results from reading only a small deflection on the scale of the voltmeter.

The voltage and resistance charts, Tables 6 and 7, are based on readings taken with a 20,000 ohm-per-volt meter. If a 20,000 ohm-per-volt meter is used in testing for the voltage, it is not necessary to consider the effect of loading.

RESISTANCE MEASUREMENTS

When a fault develops in a circuit its effect will very often show up as a change in the resistance values. Table 7 indicates the normal resistance values as measured at the tube sockets. These values are measured between the indicated points and ground unless otherwise stated. Before making any resistance measurements, turn OFF the power. If the ohmmeter is connected to a circuit which already has voltage in it, the meter may be damaged.

CAUTION

ALWAYS DISCHARGE HIGH VOLTAGE CAPACITORS BEFORE MAKING RESISTANCE MEASUREMENTS.

GENERAL PRECAUTIONS

Whenever the Crystal Impedance Meter is serviced, carefully observe the following precautions.

1. Be careful when the instrument is removed from its cabinet, dangerous voltages are exposed.

2. Careless replacement of parts often causes new faults. Therefore, observe the following points:

Before a part is unsoldered, note the position of the leads. If the part, such as a transformer, has a number of connections, tag each of the leads to it.

Be careful not to damage other leads by pulling or pushing them out of the way.

Do not allow drops of solder to fall into the set since they may cause short circuits.

A carelessly soldered connection may create a new fault. It is very important to make well soldered joints since a poorly soldered joint is one of the most difficult fault to find.

TROUBLE SHOOTING CHART

The following chart is supplied as an aid in locating trouble in the Crystal Impedance Meter Model 1207. This

Table 5

TROUBLE SHOOTING CHART

SYMPTOM	POSSIBLE TROUBLE	CORRECTION
1. Pilot lamp does not light.	Cord not plugged into A-C source, or open.	Check at source and at unit.
	Fuse F1 blown out.	Check and replace.
	Pilot lamp E1 burned out.	Check and replace.
	ON-OFF switch S1 defective.	Check and replace.
	VOLTAGE CHANGE OVER switch S2 defective.	Check and replace.
	Transformer T1 open.	Check and replace.
2. Pilot lamp lights dimly (on 115 volt source).	VOLTAGE CHANGE-OVER switch S2 set for 230 volt.	Set correctly.
Voltage regulator tube V2 does not light.	Regulator tube defective.	Check and replace.
	Rectifier tube V1 defective.	Check and replace.
	R1, R2, R3 open.	Check and replace.
	High-voltage winding of T1 open.	Check and replace.
	Capacitor C2A, C2B shorted.	Check and replace.
3. No apparent reading or deflection of grid current meter (with calibrating resistor in socket).	METER SHUNT set too low.	Turn METER SHUNT control clockwise.
	Oscillator tube V3 and amplifier tube V4 not oscillating.	Check and replace. See if tuning dial is within tuning range.
	SCREEN VOLTAGE control set too low.	Turn SCREEN VOLTAGE control clockwise.
	SCREEN VOLTAGE control defective (open).	Check and replace.
	Wiring shorted or open.	Check continuity.
	Meter open, transformer open, or oscillator coil open.	Check resistances as shown in Table 7. Check voltage as shown in Table 6.
4. Oscillates without crystal or calibrating resistor in panel socket.	Wiring disturbed in feedback or oscillator circuits.	Restore any wires which were disturbed while trouble shooting or reparing to their original positions.
	Tube shield removed.	Replace shield.
	Resistors R17 or R14 open.	Replace resistor.

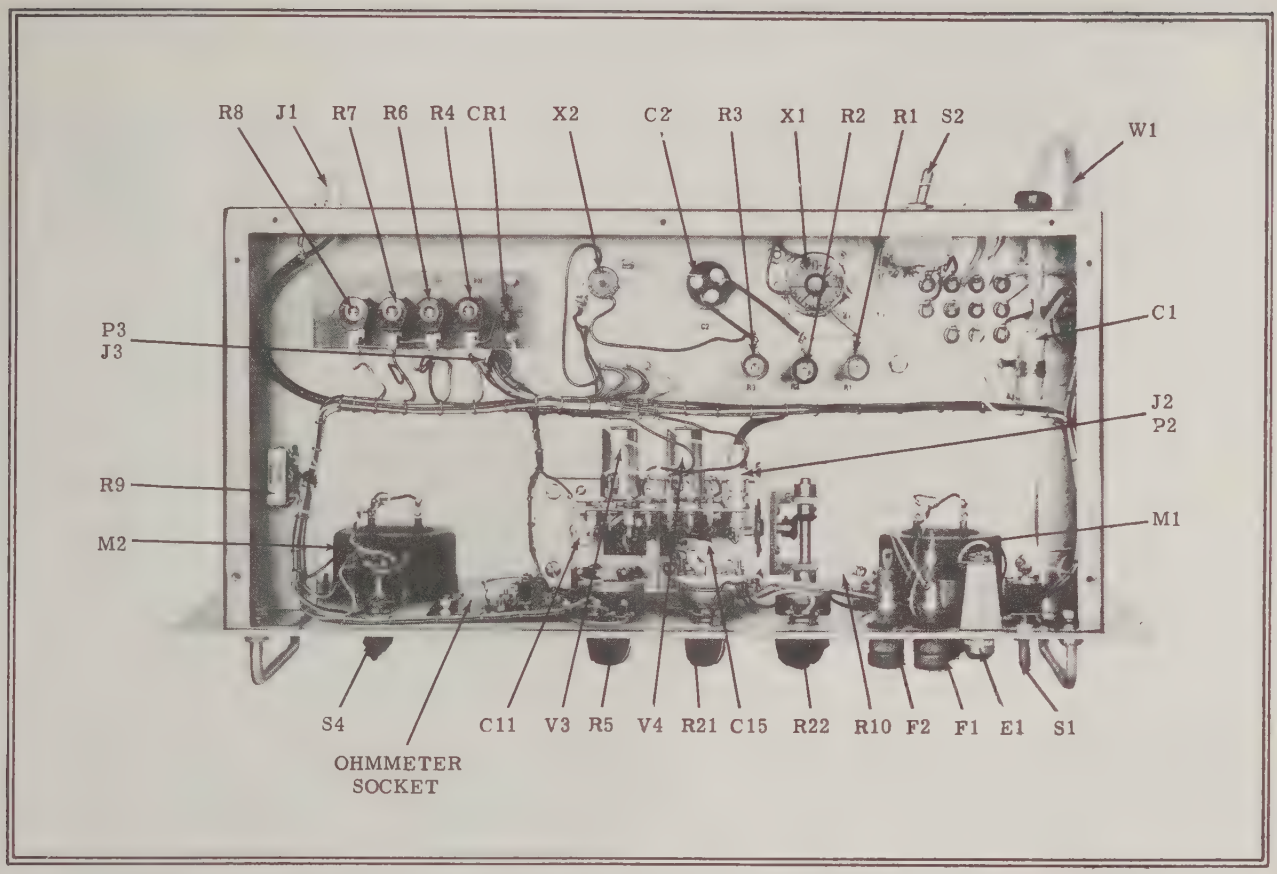

Figure 12. Bottom View of Panel and Chassis Assembly of Model 1207, Crystal Impedance Meter.

chart lists the systems which the repairman observes while making a few simple tests. The chart also indicates how to localize trouble quickly to individual stages of the Crystal Impedance Meter. Once the trouble has been localized to a stage or circuit, voltage and resistance measurements of this stage or circuit should be sufficient to isolate the defective part. Normal voltage and resistance measurements are given in Tables 6 and 7.

Note: Measure the DC resistance of the primary circuit of the power transformer from prong to prong on the AC plug. With switch S1 closed, the resistance should be about 10 ohms with switch S2 in the 115-volt position and about 40 ohms with S2 in the 230-volt position.

TROUBLE SHOOTING BY USING EQUIPMENT PERFORMANCE CHECK LIST

The Equipment Performance Check List is to be followed in numerical sequence. It lists the items to be checked, the normal indications of effect to be expected, and the corrective measures to be taken.

Action or Condition. - This column indicates what is to be done to the control of part mentioned in the item column.

Normal Indications. - The normal indications listed include the visible signs that the operator should perceive when checking the items. If indications are not normal, the operator should apply the recommended corrective measures.

Corrective Measures. - The corrective measures listed are those the operator can make without turning the equipment in for repairs.

DC RESISTANCE OF TRANSFORMER

The DC resistances of transformer T1 should correspond to the following:

TERMINALS	OHMS
1-2 (with connection to S2 opened)	20
7-8 (with connection to S2 opened)	20
3-4	320
4-5	320
6-11 (rectifier V1 removed from socket)	.1
9-10 (oscillator tubes V3 and V4 and lamp E1 removed from sockets)	.2

Table 6.

VOLTAGE CHART

All measurements taken to ground with a 20,000 ohm-per-volt multimeter.

COMPONENT PART	TERMINAL	VOLTAGE TO GROUND (DC)
C2A	(pos) -	270 V
C2B	(pos) -	200 V
V1	2	340 V
V2	1 or 5	150 (Tube lighted)
V3	1 or 7	125 V
V3	5	1.3 V
V4	1	-.2 V
V4	5	120 V
V4	6	140 V

Table 7.

RESISTANCE CHART

COMPONENT PART	TERMINAL	RESISTANCE TO GROUND (ohms)
T1	10	0.2
V1	2	30,000
V2	1 or 5	30,000
V3	1 or 7	30,000
V3	5	120
V4	1	17,500
V4	5	30,000
V4	6	15,000

REPAIRS

Replacement of Parts. - When replacement of component is necessary because of a failure, follow the disassembly procedures given in the paragraph below. It is assumed that the dust cover and bottom cover plate have been removed during the trouble shooting procedure.

Resistors. - The resistors are self-supporting. Unsoldering is the only procedure required for removal.

Fixed Capacitors. - The small capacitors are self-supporting and may be removed by unsoldering. Dual electrolytic capacitor C2 is removed by unsoldering the leads and removing the capacitor mounting nut.

Disassembly of Crystal Impedance Meter. - Loosen the set screws on all knobs and remove the knobs from the front panel. Set the dial index over one of the end graduations and record its position. Loosen the set screws in the dial and remove it from the front panel. Remove the three center screws in the dial plate and lift the dial plate off the front panel.

To remove the microammeters, loosen the stud nuts, take off the wire lugs, and remove the panel screws holding the meters.

To remove the high-frequency range tuning assembly, unplug P2 and P3. Remove the three screws that hold the coil assembly to the panel and the nut on the band switch. Note that one screw is normally hidden by the dial.

To remove ON-OFF switch S1, and the other controls, remove the respective retaining nut from each switch and control. Unsolder and tag the leads to the controls and switches.

Remove the nuts which hold the handles and the four screws which hold the panel to the chassis. The chassis assembly is now removable for repair, if required.

The Model 1207 has now been disassembled to the point where the remaining components can be removed as desired without difficulty.

Reassembly Procedure. - To reassemble the equipment, reverse the above procedures. Handle the tuning assembly carefully to avoid disarranging critical wiring.

Note: Be sure to replace the dial plate in its original position as directed in paragraph above. Carefully align the dial plate with the index at the previously recorded setting. If the shaft has been rotated the dial must be set with a radio receiver.

ALIGNMENT PROCEDURE

After repair or replacement of the components or tubes, the Model 1207 should be checked for alignment.

Equipment used for Alignment and Adjustment. - A radio receiver covering the range of 75-200 mc with dials calibrated to ±1% of frequency. The radio receiver must be equipped with a beat frequency oscillator.

Alignment of Crystal Impedance Meter Model 1207. - With the equipment operating insert the uncompensated V.H.F. variable resistor in the crystal socket. The resistor should be previously set to 100 ohms. Set the range switch S5 to 170-200 mc. Set the function switch S4 to GRID UA and turn up the SCREEN VOLTAGE until half scale is obtained on the meter M1. Turn the TUNING control until the radio receiver indicates oscillation at 180 mc. Adjust C11 and C15 for maximum grid μa.

Table 8.

EQUIPMENT PERFORMANCE CHECK LIST

	ITEM NO.	ITEM	ACTION OR CONDITION	NORMAL INDICATIONS	CORRECTIVE MEASURES
PREPARATORY	1	Line cord.	Plugged into socket of AC power source.		
	2	VOLTAGE CHANGE-OVER switch S2.	Place in proper position for power supply voltage.		
	3	SCREEN VOLTAGE control R22.	Set in full clockwise position.		
	4	METER SHUNT control R21.	Set to full clockwise position.		
	5	R-f output cable assembly.	Connect from jack J1 on rear of chassis to receiver of frequency meter.		
START	6	ON-OFF switch S1.	Turn to ON position.	Panel lamp lights.	Check plug and line cord. Check fuse F1. Check panel lamp. Check voltage source. Check transformer T1.
PERFORMANCE	7	Range switch S5.	Set to low frequency range 75-170 mc.		
	8	V.H.F. uncompensated calibration resistor set at 100 ohms.	Plug into crystal socket.	GRID UA Meter should read 50 μa or higher between 75-170 mc.	Refer to Maintenance Section.
	9	Rotary band switch S5.	Set to 170-200 mc position.		Refer to Maintenance Section.
	10	100-ohm calibration resistor.	Plug into crystal socket below nameplate.	GRID UA Meter should read 50 μa or higher between 170-200 mc.	Refer to Maintenance Section.
	11	OHM-GRID UA SCREEN VOLTS control.	Vary SCREEN VOLTAGE control.	Meter will read from 0 to 150 v as control is varied.	Refer to Maintenance Section
STOP	12	ON-OFF switch S1.	Turn to OFF position.	Panel lamp goes out. Equipment goes off.	ON-OFF switch defective. Refer to Maintenance Section.

Set the frequency range switch S5 to 75-170 mc and turn the TUNING dial over the range of 75-170 mc. The grid μa should not vary ±40% from a nominal setting over this frequency range. If dips occur check that the wiring and distributed capacitances of the circuit are exactly as originally manufactured. Readjustment of C15 may be required.

Remove the 100-ohm resistor from the crystal socket face and test for parasitic oscillations by turning the TUNING control through both the 75-170 mc range and the 170-200 mc range with the SCREEN VOLTAGE control R22 in the maximum clockwise position. No grid μa except thermal emission reading should be obtained.

With the range switch at 75 to 170 mc and 60 ohms in the socket face adjust the equipment for operation at 125 mc as indicated by the radio receiver. Loosen the three screws holding the dial and rotate it until 125 mc is under the index.

Crystal Volts Adjustment. - The calibration of the r-f voltmeter was originally accomplished by first measuring the circuit and meter resistance required to bring the meter to full-scale for .75 volts for a large number of 1N25 diodes. To an accuracy of ±5% the resistance required is 10.6 K at 125 mc. For these measurements the diode was in a holder mechanically identical to the socket face of the Crystal Impedance Meter with one side grounded and a 60-ohm resistor across the crystal socket. The average 1N25 diode calibrates with 11.3 K circuit resistance at 75 mc and 9.6 K at 200 mc. The front panel marking is set to provide this resistance change. To set the METER TO APPROX. FREQ. knob, short the meter M2 out of the circuit with a clip lead and remove the 1N25 diode from the holder. With the aid of a resistance bridge set the resistance between the insulated side of the diode holder and ground to 8.6 K by adjusting R11. Loosen the knob of R11 and reset to 125 mc. Replace the 1N25 diode.

FINAL TESTING

Equipment Required for Final Testing. - The following equipment is necessary for final testing of the Crystal Impedance Meter Model 1207.

Frequency meters covering the range from 75 to 200 mc.

Headphones or speaker.

Electronic Multimeter (Hewlett Packard Model 410B).

20,000 ohm-per-volt multimeter.

Test. - The tests below indicates whether a Model 1207 that has been repaired meets the minimum requirements for satisfactory operation.

Visual and Mechanical Inspection. - Thoroughly inspect the reconditioned Crystal Impedance Meter for loose nuts and screws; mechanical fit; and operation of moving parts, controls, and fastening devices. Check wiring, soldered connections, ground connectors, and finishes for satisfactory workmanship.

Continuity Test. - Make continuity tests to determine that all circuits are wired properly and that all connections make good electrical contact. When satisfied that no shorts exist, turn on the Model 1207 and measure voltages to ground as outlined in Table 6.

Dial Calibration. - With the radio receiver check that the dial calibration is within ±3%.

Amplitude of Oscillation. - Plug the uncompensated V.H.F. variable resistor set at 100 ohms into the crystal socket. With the SCREEN GRID control set to the maximum clockwise position tune through all ranges and note that the CRYSTAL VOLTS are always greater than .75 volts. Remove the resistor and tune through all frequency ranges and note that no CRYSTAL VOLTS or GRID UA (except grid emission) are indicated.

Crystal Power Regulation. - After initial adjustments of the Crystal Impedance Meter Model 1207 for a 60-ohm variable resistor for 1 mw dissipation, the power dissipated in a 20-ohm resistor as calculated from the readings of the CRYSTAL VOLTS meter should be less than 2 mw.

Table 9.

FINAL TEST

1. Check 115/230-volt switch.

2. Check VR tube Regulation 105 to 125 v with screen voltage max. 100 ohms in socket at 200 mc.

3. Insert crystal holder in the four front socket position for HC-6 and two positions for HC-18/U.

4. Alignment Procedure:

   Set dial at 100 mc, 100 ohms in socket.

   Adjust C15 with 100 ohms in socket at 180 mc for max. grid current.

   Adjust C11 with 100 ohms in socket at 180 mc. for max. grid current.

   Check 75-170 mc for dips with 100 ohms in socket.

   Test for parasitic oscillations on both ranges without 100 ohms.

   Dial Accuracy: Readjust dial and record dial reading.

   Set crystal volts potentiometer by:

   Setting frequency to 125 mc with 60 ohms in socket.

   Plug 410B H.P. VTVM into socket with ground away from dial.

   Set 410B to .64 volts; set R11 to .75 volts on dial of meter M2.

   Loosen set screw and set at 125 mc.

5. Check ohmmeter circuit to read 50 ohms ±2 ohms.

6. Amplitude of oscillation: .75 volts across 100 ohms throughout the frequency range.

7. Crystal Power regulation:

   With 60-ohm in socket set crystal voltmeter to .346 volts at 200 mc. The crystal volts meter should read less than .283 volts with 22 ohms in the socket.

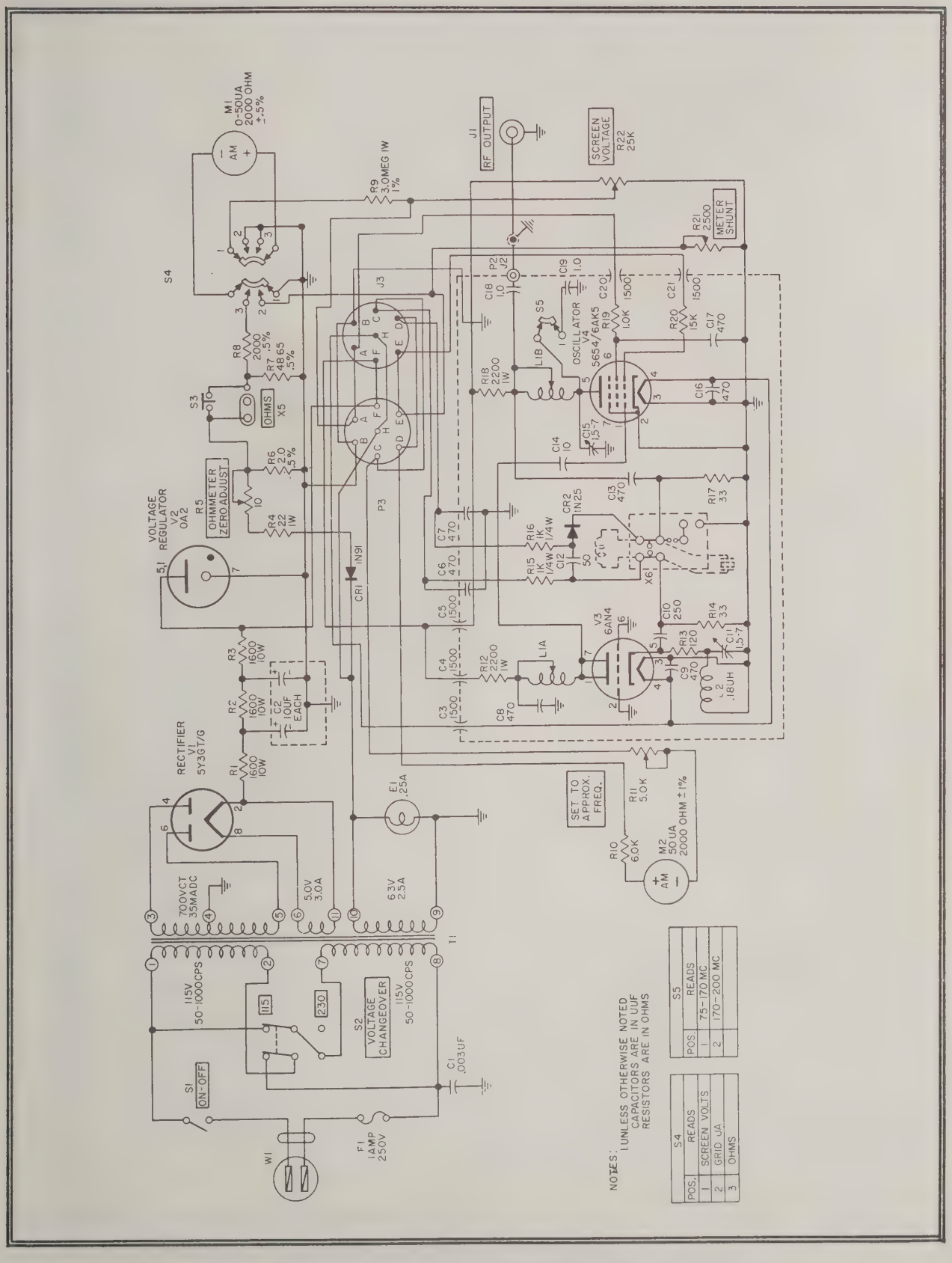

Figure 13. Schematic Diagram of Model 1207, Crystal Impedance Meter

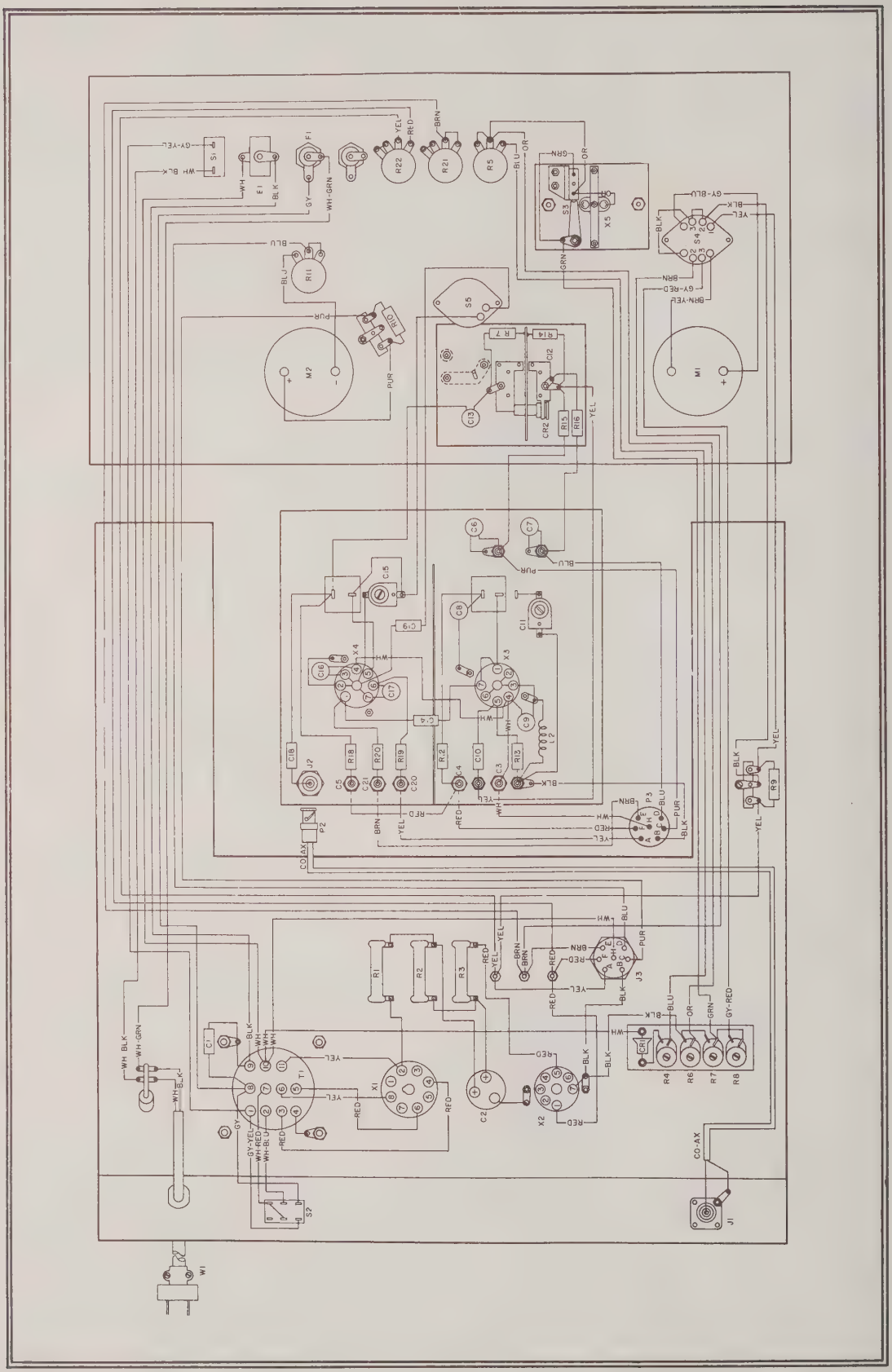

Figure 14. Wiring Diagram of Model 1207, Crystal Impedance Meter.

Table 10. Table of Replaceable Parts

MODEL 1207 CRYSTAL IMPEDANCE METER

RFL PART NO.	DESCRIPTION	REFERENCE SYMBOL	QUAN.
HB-8815	AMMETER, 0 - 50 μa, 2000 ohms, ±5%	M1	1
HB-8814	AMMETER, 50 μa, 2000 ohms, ±1%.	M2	1
HB-8919	CABLE ASSEMBLY, R.F.		1
H-1007-35	CAPACITOR, Fixed paper: .003 mf, ±20%, 600 v.	C1	1
H-1007-42	CAPACITOR, Fixed Ceramic: 1μμf, ±.25μμf, 500 v.	C18, C19	2
H-1007-164	CAPACITOR, Feed-thru: 1500μμf, +50%, -20%, 500 v.	C3, C4, C5, C20, C21	5
H-1007-186	CAPACITOR, Fixed Ceramic: 470μμf, +100%, -20%, 500 v.	C6, C7, C8,C9, C13, C16, C17	7
H-1007-187	CAPACITOR, Fixed Ceramic: 250μμf,	C10	1
H-1007-188	CAPACITOR, 10μμf, ±10%, 200 v	C14	1
HA-3748	CAPACITOR, Electrolytic: 10 - 10μf, -10%, +150%, 450 v	C2	1
HA-3751	CAPACITOR, Ceramic Trimmer: 1.5 to 7.0 μμf	C11, C15	2
HA-8915	CHOKE, .18μh	L2	1
HA-5535	CONNECTOR, Receptacle	J1	1
HA-6781	CONNECTOR, Type BNC	P2	2
HA-8835	DIODE, Silicon: 1N91	CR1	1
HA-8868	DIODE, Silicon: 1N25	CR2	1
HA-3736	FUSE, Cartridge	F1	2
HA-4109	FUSEHOLDER		2
HA-3735	LAMP, Incandescent		1
HA-3734	LIGHT, Indicator	E1	1
HA-8872	PLUG, 7 Pin	P3	1
H-1009-246	RESISTOR, Fixed Comp: 120 ohm, ±5%, 1/2 w	R13	1
H-1009-314	RESISTOR, Fixed Comp: 2.2K, ±10%, 1w	R12, R18	2
H-1009-408	RESISTOR, Fixed Comp: 15K, ±10%, 1/2w	R20	1
H-1009-610	RESISTOR, Fixed Comp: 1K, ±10%, 1/2w	R19	1
H-1009-611	RESISTOR, Fixed Comp: 33 ohm, ±5%, 1/2w	R14, R17	2
H-1009-612	RESISTOR, Fixed Comp: 1K, ±5%, 1/4w	R15, R16	2
H-1060-45	RESISTOR, Fixed WW: 22 ohm, ±1%, 1w	R4	1

Table 10. Table of Replaceable Parts (Continued)

MODEL 1207 CRYSTAL IMPEDANCE METER

RFL PART NO.	DESCRIPTION	REFERENCE SYMBOL	QUAN.
H-1060-46	RESISTOR, Fixed WW: 2 ohm, ±5%, 1 w	R6	1
H-1060-47	RESISTOR, Fixed WW: 48.65 ohm, ±5%, 1 w	R7	1
H-1060-48	RESISTOR, Fixed WW: 2 K, ±5%, 1 w	R8	1
H-1100-117	RESISTOR, Fixed WW: 1.6 K, ±5%, 10 w	R1, R2, R3	3
H-1510-201	RESISTOR, Fixed Film: 3 M, ±1%, 1 w	R9	1
H-1510-206	RESISTOR, Fixed Film: 6 K, ±1%, 1 w	R10	1
HA-8810	RESISTOR, Variable Comp: 2.5 K	R21	1
HA-8811	RESISTOR, Variable Comp: 25 K	R22	1
HA-8812	RESISTOR, Variable WW: 5 K	R11	1
HA-8813	RESISTOR, Variable WW: 10 ohm	R5	1
HA-8873	RECEPTACLE, 7 Pin	J3	1
HA-8874	RECEPTACLE	J2	1
HA-3709	SWITCH, Toggle: SPST	S1	1
HA-3710	SWITCH, Toggle: DPDT	S2	1
HA-4843	SWITCH, Subminiature: 1SM1	S3	1
HB-8821	SWITCH, Rotary	S4	1
HB-8911	SWITCH, Rotary	S5	1
HC-4466	TRANSFORMER, Power	T1	1
HA-3665	TUBE, Electron: 0A2	V2	1
HA-4795	TUBE, Electron: 5654/6AK5W	V4	1
HA-5222	TUBE, Electron: 5Y3WGT	V1	1
HA-8867	TUBE, Electron: 6AN4	V3	1
	VARIABLE HIGH FREQUENCY RESISTORS AND C_o CANCELLATION INDUCTANCES		
HB-8879	INDUCTANCE SET, as per Table 1 of Instruction Book		
H-1009-613	RESISTOR, Fixed Comp: 22 ohm, ±5%, 1/4 w		1
H-8806-1	VARIABLE RESISTOR, Uncompensated		1

Warranty

The Model 1207 75-200 mc Crystal Impedance Meter carries a warranty of 12 months from date of delivery for replacement of any part, except tubes, which fails during normal operation or service. A deficient part should be returned to the factory, shipping charges prepaid, for replacement f. o. b. Boonton, N. J.

RFL Industries, Inc.

Boonton, New Jersey, U. S. A.

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INSTRUMENTATION DIVISION • Boonton, New Jersey 07005

Tel: 201-334-3100/TWX: 710-987-8352/CABLE: RADAIRCO, N.J.